DOCUMENT RESUME

ED 374 164 TM 022 093

AUTHOR Derry, Sharon; And Others
TITLE A Microanalysis of Pair Problem Solving With and Without a Computer Tool.
PUB DATE Apr 94
NOTE 25p.; Paper presented at the Annual Meeting of the American Educational Research Association (New Orleans, LA, April 4-8, 1994).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS Computer Graphics; *Computer Software; Computer Uses in Education; Cooperation; Higher Education; *Interpersonal Relationship; *Problem Solving; Reading; *Social Behavior; Statistical Analysis; *Undergraduate Students; Videotape Recordings
IDENTIFIERS Microanalysis; *Paired Student Interaction; Problem Solving Teams; *TAPS Computer Program

ABSTRACT

The social interactions that occur during pair problem solving were studied using a computer tool and without using the tool. The computer tool, (the TAPS system) is an instructional system that presents complex word problems and provides a graphics user interface with tools for constructing problem trees (network structures showing interrelationships among sets in a problem). Subjects were 64 undergraduates who identified themselves as weak in mathematics. They were assigned to one of four treatment groups, working with and without TAPS in pairs and with and without TAPS individually. Social behavior was studied through videotaped observation. The analysis produced some modest evidence that using TAPS may have altered the nature of social interactions. TAPS pairs spent more time making suggestions to each other perhaps because of mouse control in the experimental setup and less time problem solving while reading and rereading aloud. Implications for use of such computer tools are discussed. One figure and one table illustrate the analysis. Appendixes list behavior types and contain excerpts from collaborative problem solving. (Contains 12 references.) (SLD)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED 374 164

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
☑ This document has been reproduced as received from the person or organization originating it.
☐ Minor changes have been made to improve reproduction quality.
• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy.

A Microanalysis of Pair Problem Solving With and Without a Computer Tool

Sharon Derry , Keith Tookey and Angela Chiffy
University of Wisconsin-Madison

1994 AERA Annual Meeting
New Orleans, LA

"PERMISSION TO REPRODUCE THIS MATERIAL IN OTHER THAN PAPER COPY HAS BEEN GRANTED BY
KEITH TOOKEY
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)"

Our group has been examining the ways in which two independent variables, namely (1) peer collaboration and (2) use of a specific computer tool (the TAPS system), work together and individually to shape students' cognitive and social processes during word problem solving. This research is motivated in part by the situated cognition perspective (e.g., Greeno, 1989), as well as the work of Vygotsky (1978) and others who have postulated that thinking is both physically and socially situated, meaning that problem tasks can be significantly shaped and changed by the tools made available and the social interactions that take place during problem solving. Like other researchers (e.g., Newman, Griffin, & Cole, 1989), we seek to understand whether and how problem-solving tasks are transformed by different tool use and social organizations. These questions are of general interest to the extent that peer collaboration on word problems is common instructional practice and that the TAPS system closely resembles a number of reflection-type instructional computer tools that have been implemented in recent years (e.g., Collins & Brown, 1988; Lajoie & Derry, 1993).

The TAPS System

The computer tool used in the analyses reported here is TAPS, an instructional system that presents complex word problems and provides a graphics user interface with tools for constructing problem trees. Problem trees are network structures showing interrelationships among all relevant sets in a problem situation, specifying the subgoal structure of the problem, and illustrating a solution path. By constructing and labeling a tree, students make explicit their semantic and structural understanding of concepts and relationships that underlie their choice and sequencing of arithmetic operations. Such trees provide graphic reifications of abstract structures that otherwise would be implied, making them public and available for discussion, manipulation, and comparison. Theoretically, this type of environment should encourage and afford reflection, strategic planning, and metacognitive awareness (e.g., Reusser, 1992; Collins & Brown, 1988), producing positive immediate and residual effects on problem solving. An example TAPS screen is shown as Figure 1.

Insert Figure 1 and Table 1 About Here

As TAPS was designed as a tool for developing metacognitive awareness through collaborative problem solving, we have previously analyzed the effects of collaboration and TAPS use on such metacognitive processes as strategic planning and monitoring (e.g., Derry, Tookey, & Roth, 1993). Our analysis showed that college students who engage in collaboration while solving complex word problems exhibit significantly more monitoring behavior than do students who think aloud while solving the same word problems alone. Also, we found that students who solve problems with TAPS exhibit significantly more planning behavior than do students who use conventional tools (pen, paper, and calculator). Moreover, TAPS use plus collaborative problem solving produced additive effects that together greatly enhanced students' tendencies to plan. In general, these

TM022093

BEST COPY AVAILABLE

observations suggest that social problem solving with TAPS might significantly shape students' problem solving processes in potentially productive ways. However, findings have been ambivalent in important respects. For example, although enhancements in self-regulatory and planning behavior have been accomplished, and even though such enhancements are considered desirable by the research community (e.g., Schoenfeld, 1987), our studies have thus far produced only modest, statistically unreliable, improvements in problem solving success and transfer performance. Moreover, a possibly undesirable effect of collaborative problem solving on the TAPS system is a significant reduction in problem-solving efficiency.

Purpose of Present Study

Such ambivalent findings, combined with rapidly growing faith in the pedagogic value of collaborative, reflective problem solving with computers, indicate a need for cognitive microanalyses that examine the nature and effectiveness of the social interactions that occur when students collaborate to solve problems both with and without reflection-type computer tools. Accordingly, the purpose of this analysis was to gain deeper understanding of the social interactions that occur during pair problem solving, both with and without the TAPS system. Since the concept of situated cognition suggests that the introduction of new thinking tools can alter social cognitions, and since tools like TAPS are designed to enrich social interaction, we began by asking whether differences in social interaction would be observed when comparing groups who solved problems with TAPS versus those who solved problems using conventional tools (pen, paper, and calculator). In addition, we sought to describe in detail the differences between productive versus unproductive collaborative problem solving, and to identify factors associated with effective and ineffective collaborative behavior. Another purpose was to examine these interactions with an aim toward evaluating their relative effectiveness for accomplishing specific pedagogical goals related to the enhancement of problem-solving ability. For example, we sought to understand the extent and circumstances of peer tutoring that takes place naturally in collaborative problem solving. Another aim of our study was to derive from our analyses some principled ideas pertaining to how reflective computer tools or the broader instructional environment might be designed for the purpose of enhancing the instructional value of group interactions.

Method and Data Source

Volunteer subjects, who identified themselves as weak in mathematics, were solicited from a large undergraduate educational psychology course. They received course credit for participation. Sixty-four students were randomly assigned to one of four treatment conditions. In Treatment 1, eight pairs of students worked collaboratively on several practice and one target word problem using the TAPS system. Treatment 2 was identical in that eight student pairs worked collaboratively on identical problems, but differed in that these students worked without the TAPS system, using pen, paper and a calculator for developing their joint solutions. Treatment 3 was identical to treatment 1 except that students worked on TAPS individually rather than in pairs. Treatment 4 was identical to treatment 2 except that students worked without TAPS individually, rather than in pairs. Two target problems were used in the study, given to subjects in counterbalanced order. The discussions in this paper use only the example target problem shown in Figure 1.

Protocols of problem-solving sessions were videotaped for analysis. For the analyses of collaborative problem solving reported in this paper, only the pair data (treatments 1 and 2) were examined.

Analyses and Results

Analysis I. The purpose of this analysis was obtain a descriptive profile of the social behaviors exhibited during collaborative problem solving and to test the hypothesis that the introduction of a thinking tool (the TAPS system) into collaborative problem solving would alter the nature of the social interactions. Data for this analysis was obtained by studying each fifteen-second interval on each tape and assigning codes to indicate what social behaviors were observed during each interval. The coding system, provided as Appendix A, permitted a detailed description of each individual's social problem solving behavior. The coding system represented a synthesis of ideas from the literature on metacognition and social problem solving (e.g., Schoenfeld, 1987; Clements & Nastasi, 1988; Arzt & Armour-Thomas, 1992). The reliability of the coding system, as measured by percentage of agreement between independent raters, exceeded .90.

Based on coded data, TAPS and non-TAPS pairs were then compared for each major category and sub-category of social behavior, using an adjusted Mann-Whitney procedure that is suitable for small sample size and does not require homogeneity of variance.

This analysis, summarized in Table 1, produced some modest evidence that introducing the computer tool may have altered the nature of social interactions in very specific ways. Two statistically significant differences were found. First, pairs in the TAPS condition spent proportionately more time making suggestions to each other than did non-TAPS pairs. This appeared to have a simple explanation based on a small difference in the experimental setup: Since only one person at a time could control the mouse in the computer condition, the other person was required to make suggestions (short of commandeering the mouse) in order to fully participate. By contrast, in the non-computer condition, both members of the pair had pens and could write on the paper at will. Had only one pen been provided, more suggesting might have occurred in that treatment as well, although the conditions in our study did parallel those typical of actual learning situations.

Second, non-TAPS pairs spent proportionately more problem solving time in reading and rereading (aloud) than did TAPS pairs. As we noted in previous analyses (Derry, Tookey, & Roth, 1993), presentation of word problems by computer tends to reduce proportion of problem solving time spent in the reading process. In pen-and-paper conditions, reading parts of the problem text out loud to one's partner is a more frequently used part of argumentation and discussion.

Given the large number of comparisons made, we interpret tests of statistical significance with caution. However, the analysis did provide modest evidence that the introduction of the TAPS tool altered specific aspects of social interaction by reducing reliance on reading and increasing students' tendencies to make suggestions. Perhaps more striking, however, are the obvious between-group similarities in the overall patterns of social interaction shown by the data of Table 1. In both conditions, more time was spent giving as opposed to receiving help. There was little conflict or domination, but a great deal of negotiation in both conditions. With the exception of some uncooperative leading, which occurred in both conditions, there were no "nonsocial" behaviors in either condition. With the possible exception of the reading category, we find little evidence for any major differences in the nature of the social interaction produced by introducing the computer tool.

Analysis II: Qualitative Analysis of Pair Problem Solving Protocols. We also prepared a detailed qualitative description of each problem solving session to determine precisely what occurred during pair problem solving in each of the protocols. Excerpts from the texts of 7 such descriptions, selected to represent a range of problem-solving behaviors and issues, are given as Appendix B. With no coding scheme imposed other than our viewpoints as cognitive and educational psychologists, we analyzed these data in

an attempt to develop hypotheses regarding the following issues: What are the key processes of collaborative pair problem solving that are likely to mediate its effectiveness as a method for achieving problem solving goals and for learning from one another? In what ways might it be possible to improve the effectiveness of collaborative problem solving as a pedagogical tool? Some conclusions from this analysis are summarized below:

1. The Importance of Insight

Most of the problem solving observed in our samples exhibited a decided Gestalt-like quality in that it proceeded largely by data-driven search followed by insightful problem understanding. Pairs proceeded by reading, reflecting, and sometimes floundering until an insight that was the key to the problem solution became obvious, often quite suddenly.

Efficient pairs behaved as follows: After a short period of thoughtful reading and reflecting, a single insight that is key to the solution is experienced by one partner, who is able to quickly bring the other partner to understanding of the insight. They solve the problem with little monitoring or checking. Examples of relatively efficient problem solving are given as protocols POLT1, POLP1, and POLP3 in Appendix B.

Inefficient but successful pairs also relied heavily on data-driven search and insight. However, inefficient pairs often experienced a number of piecemeal insights rather than one key organizing framework. As shown in protocols POLT2, POLT3, and POLP2 of Appendix B, sometimes an insight can be incorrect; or it may a relevant one but not the full "key" to the solution. Weaker pairs had difficulty evaluating their insights and may consequently abandon good insights without exploring their implications. This occurs often in POLT3, for example.

2. Peer Tutoring Opportunities

Whenever one person experienced what they perceived to be an important insight into the problem, they inevitably attempted to share it with the partner. This was always the point where some degree of coaching or peer tutoring occurred, as the person with understanding tried to coax the partner to see and accept it. This coaching also served to help the mentoring partner articulate and check his or her own understanding.

As illustrated in POLT2, POLT4, and POLP1, collaborating often introduced a new dimension into the process of defining what the problem was about: a significant part of the problem became "selling" an idea to an uncertain or questioning partner. "Selling" can be more argumentative than merely explaining, as the partner may be doubting or questioning (see below).

3. Competing Understandings

It was not uncommon for the two solvers to promote competing understandings and approaches. For example, in one protocol (not described here) a partner was attempting to work forward from givens and repeatedly scrolled the workspace to permit the adding of steps below the first one. The other partner, believing they would be working backward from the goal, would repeatedly counter by scrolling the computer screen so that they could add steps above their first entry. Neither partner understood what the other was thinking.

Since complex word problems can be solved with different strategies and solution paths, it is quite possible that both competing understandings may be valid. Competing valid viewpoints are illustrated in protocols POLT2 and POLT3. In these protocols, the dominant partner is imposing a viewpoint, although it is as the expense of another valid viewpoint held by a weaker partner. The solutions in these protocols as much socially imposed as they are "cognitively negotiated" (Clements & Nastasi, 1992).

4. Computer Difficulties

A significant factor accounting for speed differences between TAPS and non-TAPS conditions was that a few students were slow and awkward with a computer mouse. This is the case with Ann in protocol POLT3.

5. TAPS and Representation

TAPS can complicate problem solving in the following way: For some subjects using the system there were two separate stages to problem solving: obtaining an answer followed by the problem of representing the tree on the system. This was the case for Bob in POLT2 and Joe in POLT3. Sometimes the representation stage was regarded as a check on an original solution hypothesis, which is the case for Joe in POLT3.

By contrast, for some subjects using TAPS the processes of representation and solution finding are fully integrated. That is, some subjects employed the TAPS tools to help them understand and solve simultaneously while others employed TAPS to help them make visible an otherwise hidden, mental problem solving process. For example, POLT1 (an integrated representation) can be compared to both POLT2 and POLT3.

This added complication affects social interaction to the extent that an added complication makes the problem, and hence the required communication, more complex.

6. Heuristics and Strategic Planning

The most common problem solving strategy is data-driven search for insight. For better problem solvers, this strategy is very efficient and effective. For poor problem solvers, this strategy has a different appearance. For example, the POLP3 pair appear to read and reread, rather haphazardly, and wait for insightful understanding to surface. As insights occur, monitoring helps the pair question current beliefs, indicating when things don't make sense, pointing out constraints that are violated, and helping the pair avoid wild goose chases. This strategy is ultimately successful, but very inefficient.

Pairs, especially less effective problem solvers, sometimes consciously used heuristics to help them search the problem space. For example, the pair in POLT4 try several heuristics, such as "examine the goal statement first" and "pull out the numbers." In POLT2, Bob suggests that they break the problem down. Sometimes these heuristic activities successfully lead to insights and sometimes they don't. In POLT4, several heuristic strategies are tried and these all lead to some significant insight, but none of these insights are pursued deeply and long enough to lead to a correct understanding. These problem solvers appear to jump from idea to idea, abandoning each before important relationships are found.

7. Functional Fixedness:

In POLT4, the pairs fails to discover that the set of votes that equalizes the in-favor and opposed groups is the same set that "switches" from uncommitted to opposed. Like other pairs, they are miscued by the problem word "switched." However, while many other pairs eventually overcome this miscue, this pair is strongly fixated on it, which prevents them from considering other interpretations. This is an example of functional fixedness, which hindered problem solving in a number of cases.

Improving Collaborative Problem Solving

Our analyses suggested to us several ways in which collaborative (as well as individual) problem solving might be improved through training.

First, since problem solving appears to be a data-driven search for insight, and since insight is believed to be based on recognition and reorganization of the conceptual patterns underlying problem situations, it follows that problem solving training should include the following: 1) Schema training (e.g., Marshall, in press), which teaches students to name and recognize set patterns found in problem situations; and 2) Planning

strategy training, procedures for connecting basic schemas together to create holistic, complex problem models. Planning strategy training here refers to the teaching of specific procedures for chaining basic schemas together, such as working backward in stepwise fashion from a goal. Students in our study appeared to be searching for and reorganizing patterns in the insightful learning sense described by Sternberg (1988), although they were not likely explicitly aware of their processes. Making basic underlying patterns and organizing strategies explicit as tools for problem solving should increase the efficiency of students' insightful learning process. Moreover, it should increase the efficiency of collaborative processes by introducing a common language for articulating their approaches to one another.

We also believe that collaborative problem solving might be improved by training in social processes that makes students explicitly aware of unproductive collaborative behaviors, such as leading without effective tutoring, while enhancing their awareness of productive collaborative behaviors associated with effective cognitive negotiation. For example, the data of Table 1 indicate that clarifying, rule determination, and correcting were infrequent behaviors, although these are important to the group problem solving process and students could be taught to use them.

Further, if students are expected to learn about problem solving through collaboration, they can be given instructions that encourage cognitive, rather than social negotiation. If students believe that their main responsibility is to solve a problem correctly as fast as possible, then the partner who experiences insight will lead and will not necessarily tutor the other partner to understanding. However, if it is made clear to students that they must both understand and agree on their solutions, then more effort to help and explain may result. Further, it should be possible to sensitize students so that they will recognize opportunities for teaching, and possibly to train them to use more effective tutoring strategies.

References

Artzt, A. F., & Armour-Thomas, E. (1992). Development of a cognitive-metacognitive framework for protocol analysis of mathematical problem solving in small groups. *Cognition and Instruction,* 9(2), 137-175.

Clements, D. H. & Nastasi, B. K. (1988). Social and cognitive interactions in educational computer environments. *American Educational Research Journal, 25(1),* 87-106.

Clements, D. H. & Natasi, B. K. (1992). The role of social interaction in the development of higher-order thinking in Logo environments. In E. DeCorte, M. C. Linn, H. Mandl, & L. Verschaffel (Eds.) *Computer-based learning environments and problem solving.* Berlin: Springer-Verlag.

Collins, A. & Brown, J. S. (1988). The computer as a tool for learning through reflection. In H. Mandl & A. Lesgold (Eds.) *Learning issues for intelligent tutoring systems (*pp. 1 - 18). New York: Springer-Verlag.

Derry, S., Tookey, K., & Roth, W. (1993). AERA Presentation, Atlanta, GA.

Greeno, J. G. (1989). A perspective on thinking. *American Psychologist,* 44, 2, 134-141.

Lajoie, S. & S. Derry (Eds.) (1992). *Computers as Cognitive Tools.* Hillsdale, NJ: Lawrence Erlbaum Assoc.

Marshall. S. (in press) *Schemas in Problem Solving.* Cambridge Univ Press

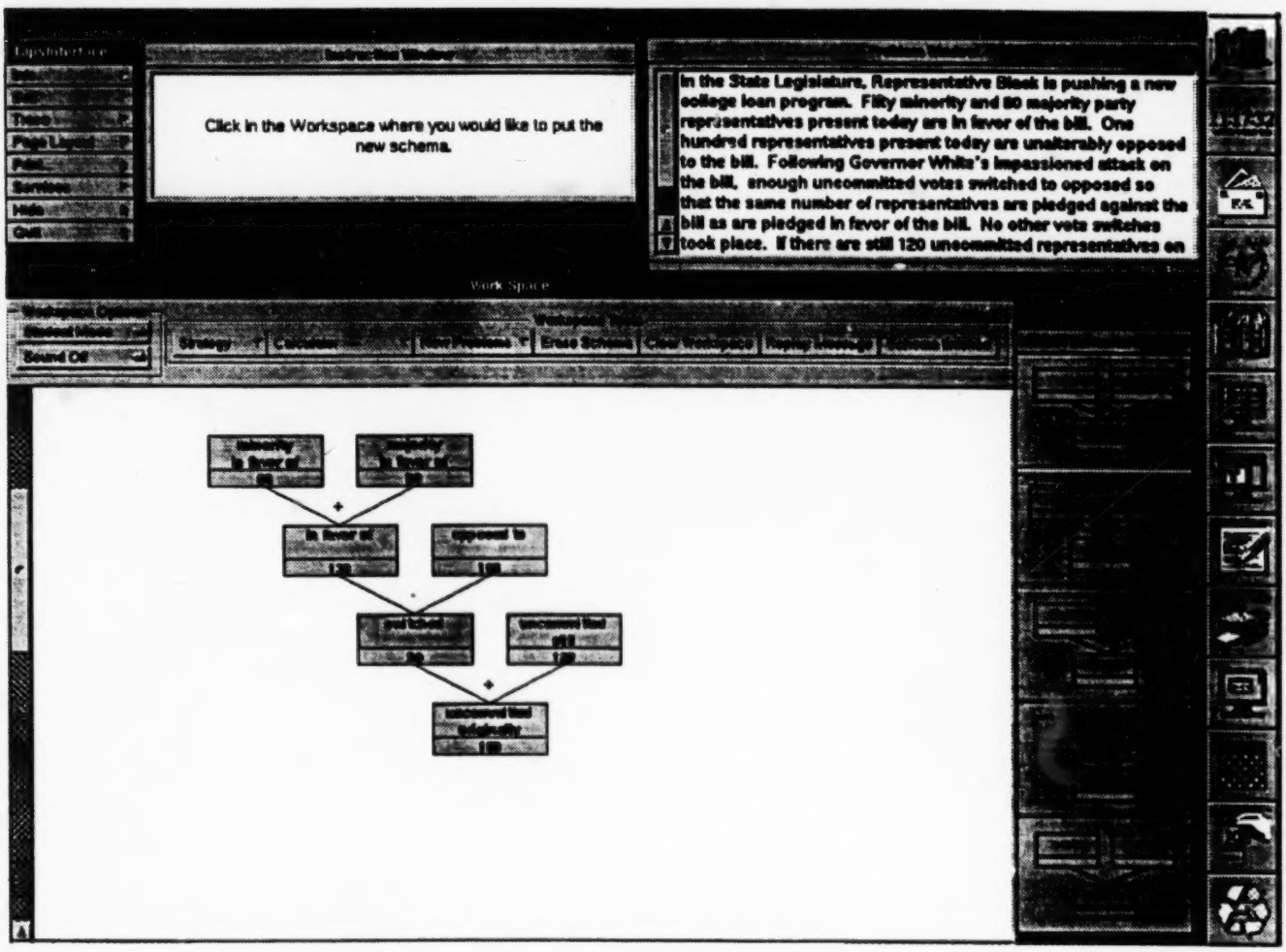
Reusser, K. (1992). Tutoring systems and pedagogical theory: Representational tools for understanding, planning and reflection in problem solving. In S. Lajoie & S. Derry (Eds.) *Computers as cognitive tools (pp. 143-179).* Hillsdale, NJ: Erlbaum.

Schoenfeld, A. H. (1988). What's all the fuss about metacognition? In A. Schoenfeld (Ed.) *Cognitive science and mathematics education* (pp. 189 - 216). Hillsdale, NJ: Erlbaum.

Sternberg, R. (198X). *The Triarchic Mind.* New York: Penguin Books.

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner, & E. Souberman, Eds. and Trans.). Cambridge, MA: Harvard University Press.

Figure 1.Taps Screen


Click in the Workspace where you would like to put the new schema.
In the State Legislature, Representative Black is pushing a new college loan program. Fifty minority and 80 majority party representatives present today are in favor of the bill. One hundred representatives present today are unalterably opposed to the bill. Following Governor White's impassioned attack on the bill, enough uncommitted votes switched to opposed so that the same number of representatives are pledged against the bill as are pledged in favor of the bill. No other vote switches took place. If there are still 120 uncommitted representatives on
Work Space

Problem text continued: On this bill how many were uncommitted before Gov. White's speech?

BEST COPY AVAILABLE

TABLE 1 Results of Adjusted Mann-Whitney Test: Hypothesized Treatment Effects (Percent of 15 Second Intervals Including Each Type of Activity)

	PP: Pair with Pen/Paper		PT: Pair with TAPS		
	mean	SD	mean	SD	Z
OBTAINING INFO OR HELP	38.93	14.77	38.45	16.47	-0.20
Asking	15.03	5.88	20.40	10.58	-0.53
Attending	15.06	11.53	4.58	5.32	1.09
Clarifying	1.29	1.48	1.48	1.91	-0.03
Using	11.68	13.36	20.29	6.17	-1.20
Consensus Testing	7.62	5.04	10.01	6.17	0.60
Rule Determination	0.35	0.65	0.21	0.39	0.07
GIVING INFO OR HELP	67.33	20.61	74.26	4.98	0.40
Answering	14.74	4.31	15.68	7.89	-0.06
Correcting	6.64	5.19	3.21	2.68	0.48
Giving	26.39	15.65	25.27	11.34	-0.06
Justifying	16.68	5.60	8.00	8.41	1.00
Suggesting	6.42	3.84	20.55	7.32	2.53*
Supporting	5.94	7.18	11.14	9.62	-0.83
Agreeing	16.94	7.96	22.72	8.77	-0.55
Reading	36.51	14.31	15.05	8.90	2.09*
NONSOCIAL BEHAVIORS					
Unsupportive	0.74	2.09	0.00	0.00	0.50
Negative Affect	0.00	0.00	0.40	0.56	-1.09
Isolating	0.00	0.00	0.00	0.00	0.00
Leading	23.46	18.19	19.98	18.95	0.11
Not Attending	0.00	0.00	0.06	0.18	-0.50
EPISODES					
Conflict	4.46	8.48	0.91	1.82	0.07
Resolve	1.78	3.29	0.30	0.85	0.37
Negotiate	76.30	33.79	94.43	8.48	-0.86
Dominate	8.12	14.07	1.94	3.31	0.10
POSTTEST CORRECTNESS (0-3 for each of two problems, summed)	3.75	1.04	5.19	0.72	-1.59

*P<.05

Appendix A: SUPPORTIVE/TASK-ORIENTED BEHAVIORS:

I. Obtaining Information or Help from Other Participant(s):

I. Ask:* Asking: Questioning Other/Asking for Help, Information or Suggestion

Questioning occurs when a problem solver requests information ("How much did it say the discount was? "What does that word mean?") or a clarification ("Why did you do that?"). (Asking for the other to confirm information would usually be coded as *I. Con*, not *I. Ask.*) This category includes direct requests of help from another problem solver ("Could you run the mouse?"); expressions of puzzlement or bewilderment with a question ("What am I missing?"), and pleas for help due to uncertainty or confusion ("What do I do now?"; "Where do I go now?"; "Help, I don't understand this!").

I. Attend: Attending: Watching/Listening/Learning from Other

One student observes the other and/or listens to the comments of another. If there is evidence the student is not paying attention and therefore not involved, it is coded as *III. Not Attend*. Listening as part of interaction need not be coded as attending. If there is a lengthy period with no participation by one person, it should be coded as attending as either attending or not attending.

I. Clar:* Clarifying Other's Meaning: Restating/Paraphrasing /Clarifying Statement

This type of clarification occurs when a student re-states another problem-solver's assertion in his/her own words, seemingly for the purpose of ascertaining understanding of the other's point. It is not *I. Use* in that it does not add additional information to, nor extend the conversational meaning. This code can be used for a clarification of an action taken by another problem solver. The code *I. Clar* is used only if one is trying to understand what another is saying or doing. If one is clarifying the problem or a point for the benefit of the the problem solving team, then it is coded as *II. Prov* (providing information in the form of clarification).

I. Use:* Using: Elaborating, Extending, or Acting Upon Another Problem Solver's Idea

Elaboration is expanding on another's statement or ideas by extending with knowledge and ideas contributed by the student who is doing the elaborating (background knowledge). Elaborations differ from paraphrases in that they add new information to the problem situation that is not part of the current conversation. For example, referring to how Domino's sets prices on their pizzas to extend a discussion about pizza would be an elaboration. The process can include one student starting a statement ("We know how to do this...") and the other finishing the statement ("because it's just like the pizza

problem!"). Extending is continuing an idea further in the same way or direction. Acting Upon is using a suggestion given by the other. Elaborating, Extending, and Acting Upon all involves ways of using another's ideas.

I. Con:* Consensus Testing: Inviting Partner to Agree or Disagree with Action or Idea

Testing consensus is asking for correction or confirmation on a particular point or move("Is the discount $2?; Do you want to do Pizza One next?"). This can take the form of a direct question (as above), an indirect question ("The discount is $2, don't you think?") or a statement with a final inflection indicating a question ("It's a $2 discount", with a raised tone on the word "discount").

I. Rule:* Social Rule Determination:

When any information request involves what social rules to go by while working together, it is coded as *I. Rule*. Deciding how to divide work among problem solvers is rule determination. ("How do you want to do this, me do the writing?" "Do you prefer to run the mouse while I say what to put in the boxes?") All the categories listed I above can be coded in conjunction with rule determination. That is, one can be asking information, elaborating, seeking consensus, etc. about the social rules of problem solving.

II. GIVING INFORMATION OR ASSISTANCE

II. Answer: Answering Question

Answering a question is either directly or indirectly responding to a question that has been asked. Indirect responses include acting so as to make the answer to the question obvious, which is also coded as *I. Use* (as in, the answer to the question 'should the discount be $4 and not $2?' might be to change the discount from $4 to $2.)

II. Correct:* Correcting: Initiating Correction or Registering Disagreement

Disagreements occur when a statement is made or an action is done with which the other student does not concur ("The discount is $2."; "No, it is $4.) Thus, two statements (or an action and a statement) which are contradictory must have been made for a conflict to occur. If a student asks a question (i.e. "Is the discount $2?") and another responds (i.e., "No, it's $4"), this is not conflict because conflict occurs when students hold opposing views to be true. This is because initial questions (like the one above) do not necessarily show that the student believes the statement. These questions may indicate that the student is seeking clarification rather than making a statement of fact.

II. Give: Providing: Giving Info or Opinion

Providing is giving information or opinion not in response to a question (see *II. Answer*) or as a correction (see *II. Correct*). Providing is often followed by *I. Use* the provided information.

II. Justify:* Justifying: Explaining/Giving Reasoning for Action or Opinion

Justification is when students use a portion of the problem to defend their position. Students can use elaborations and paraphrases in the process of justification as well as citing exact wording from the problem. Justification can be done in response to a question or can be done spontaneously.

II. Suggest:* Suggesting Action or Interpretation:

Suggesting is a tentative means of inputting information (see *II. Give*). Tentative implies that it is an option for discussion, as opposed to something that is believed to be best or true.

II. Support: Supporting: Cheerleading/Expressing Positive Affect/Partnership

Support involves showing pleasure at something in the problem or system ("That was great!!"), display of positive attitude or behaviors towards another ("Good job!", "Well done!"), an act of encouragement ("You can do it!"), expressions of understanding ("Now I get it!"), certainty ("I know this is right,"), expectations confirmed ("I knew it!"), or acknowledgement of shared situation ("I don't know either" or "We're in this together"). Laughter with another can be a supportive activity. An 'OK' after a task is completed can be coded as supportive.

II. Agree: Agreeing: Agreeing with Statement of Another

Agreement is stating agreement with a previous statement by another. This does not include implicit agreement by *I. Use*. Agreement with affective statements is coded as *II. Support*.

II. Read: Reading:

One or both students reads the problem aloud. It is assumed that when only one student is reading aloud that the other is reading silently unless there is evidence to the contrary. Thus, both students are engaged in reading and are working in parallel.

III. NONSOCIAL BEHAVIORS:

III. Unsupport: Unsupportive behavior/criticism:

Unsupportive behavior is any display of negative behaviors towards another ("That's dumb", "You're too slow") as an act of discouragement. Laughing at (as opposed to with) another is unsupportive. These are not corrections, as they do not focus on any act (or its correctness) in particular. They are not negative affect as they are directed towards another person and not the system. Ignoring, disregarding, or overriding objections, questions, or hesitations of another is unsupportive.

III. Negative: Negative Affect:

Showing displeasure at something in the problem or the system ("That really rots!").

III. Isolate: Isolating, Working Alone Uncooperatively:

Work in isolation or parallel is when students are working individually. They may be working on the same activity or different activities at the same time. This also includes times when one student is on-task and the other is off-task. If there is an attempt to co-ordinate the activities, the coordination is coded as *I. Rule*.

III. Lead: Leading/Imposing/Forcing Own Way:

One person takes the lead with the tacit approval of the other, or follows their own agenda while ignoring, disregarding, or overriding objections, questions, or hesitations of the other. If lead is taken over the objection of another, there will often be some indication (such as *III. Unsupport*) and if lead is taken after discussion that is usually coded as *I.Rule*.

III. Not Attend: Not Attending:

There is evidence (wandering attention, missing dialog) that the person is not paying attention to either the task at hand or to the partner.

IV. EPISODES:

IV. Conflict: Conflicting Episode/Argument/Disagreement

Disagreements occur and Conflicting Episodes begin when a statement is made or an action is done with which the other student explicitly does not concur ("The discount is $2."; "No, it is $4.) This can occur with invitation (*I. Con*) or without (*II. Correct*). Either way, two statements (or an action and a statement) which are contradictory must have been made for a Conflicting Episode to begin. If a student asks a question (i.e. "Is the discount $2?") and the other responds (i.e., "No, it's $4"), this is not conflict because conflict occurs when students hold opposing views to be true. This is because initial questions (like the one above) do not necessarily show that the student believes the statement. These questions may indicate that the student is seeking clarification rather than making a statement of fact. The Conflicting Episode can be ended by *IV. Resolve*. If the two agree (explicitly or implicitly) to let it ride, the Episode is regarded as suspended rather than *IV. Resolved*. If Imposing/Dominating/Forcing Own Way occurs, the Episode is regarded as suspended rather than *IV. Resolved*. Before two can become involved in a *IV. Negotiate* Episode or a *IV. Dominate* episode, the Conflicting Episode must be either *IV. Resolved* or suspended.

IV. Resolve: Conflict Resolution

Resolution is the integration of differing opinions from a conflict episode. Successful resolution is when both students agree on a meaning or course of action after a disagreement. If a conflict is "put aside" by both students, this is not considered to be resolution. Conflict Resolution occurs at a particular point (when the new agreement is stated) and closes a Conflicting Episode/Argument/Disagreement.

IV. Negotiate: Negotiating Episode/Discussion/Cooperation

Negotiating Episodes are episodes of working together without conflict. Negotiating Episodes cannot occur while a *IV. Conflict* Episode is active; they also cannot occur while a *IV. Dominate* Episode is active. Any activity that is not a Supportive/Task-Oriented Behavior (*I* or *II*) ends a Negotiating Episode. Any cooperative Supportive-Task-Oriented Behavior(*I* or *II*) while neither a *IV. Conflict* nor a *IV. Dominate* is active begins a negotiating Episode.

IV. Dominate: Social Domination Episode

Social Domination Episodes are always begun by imposing, which is coded as *II. Lead*. They are considered ended by any **II. Giving Information or Assistance** by the dominated partner. They are also ended by the beginning of a *IV. Conflict* Episode. A *IV. Negotiate* Episode cannot begin until the Social Domination Episode is concluded.

*Metacognitive category

APPENDIX B: EXCERPTS FROM QUALITATIVE ANALYSES OF SIX COLLABORATIVE PROBLEM SOLVING SESSIONS

Four Pair Solutions of the Politics Problem on TAPS

I. Protocol Description: Politics Problem on TAPS , Pair 1 (POLT1)

POLT1 consisted of two female subjects, "Tanya" and "Linda," who worked the problem correctly in about 5 minutes. This is an example of efficient problem solving that proceeds smoothly without difficulty

In the beginning of the session, substantial time and effort is devoted to reading. Both students actively engaged in reading and rereading, which appeared thoughtful and reflective in style and involved selective focusing on specific parts of the problem statement. However, that this thoughtful reading did not produce a complete problem understanding is illustrated by hesitation and expressions of uncertainty at the point where actual solution activity begins.

The pair begins problem solving by starting a schema on screen with two sets, "number in favor" and "number opposed." Before choosing an arithmetic operator, the students engage in discussion, during which Linda experiences a critical organizing insight that is key to the entire solution. As illustrated in the protocol below, she shares her insight with Tanya, who is controlling the mouse, by leading her through subsequent solution steps. Although in the end both students agree that they are satisfied with the problem solution, the construction of the solution from the point of Linda's insight is entirely guided by Linda.

Protocol Excerpt: POLT1

On screen:	number in favor	number opposed
	130	100

1.	T:	OK. (rereading) Following Gov White's impassioned attack on the bill, enough uncommitted votes switched to opposed so that the same number of representatives are pledged against the bill as are pledged in favor of the bill.
2.	L:	There are still 120 uncommitted. So they're saying these two (points to screen) are equal now?
3.	T:	Right.
4.	L:	So then 30 of uncommitted go over . . . 130 minus 100 . . . that's how many switched over. Just add that onto 120.
5.	T:	Is that right (using mouse to label third set)? Switched?
6.	L:	Which one of these (referring to computer triad diagrams) go forward because you're gonna have to put 120 plus 30 now.
7.	T:	(chooses and attaches correct blank triad)
	//	(// indicates part of protocol deleted)
8.	L:	Put switched and 120
9.	T:	120?
10.	L:	Yeah, add those together. It should be how many were originally uncommitted. So put originally.
11.	T:	(works solution on computer)
12.	L:	Quit. Schema finished, that's it.

II. Protocol Description: Politics Problem on TAPS Pair 2 (POLT2)

POLT2 was composed of two males who required 15.25 minutes to obtain a correct solution. This protocol illustrates a situation in which each member of the pair is approaching the problem with a different, potentially successful, thinking strategy. However, one member of the pair ("Bob") is a stronger personality and also is making faster progress toward understanding than is the slower and less dominant "Mel." By assuming leadership Bob invalidates some of Mel's potentially useful insights. The final solution tree is largely socially imposed, as opposed to cognitively negotiated, and there is some evidence that Mel's understanding of the resultant solution is weak.

After Mel reads the problem through once, Bob immediately takes charge. His initial approach seems to be guided by general motivational and problem solving heuristics such as "Just do it," and "Break it down:"

1	B:	Let's just kind of do it (gets blank schema, puts on screen) . . . . . We need to break it up as far as committed, uncommitted, and unalterable. Let's re-read real quick to see if we missed anything.
2	M:	You read it out loud.
3	B:	Fifty majority and eighty minority present today are in favor of the bill. So we might just start out to build that and get it out of mind.
4	M:	OK
5	B:	Label this in favor of . . . . (Bob directs on screen construction of following:)

in favor blank
130

blank

Following this entry, Bob rereads and reasons aloud until he experiences insightful understanding that gives him the answer, although he does not know how to represent his solution with the computer system. Mel neither understands nor agrees with Bob's (correct) reasoning and wants to think about the problem differently:

6	B:	We'll figure out how to put it in a schema but as I see it (points to screen) we've got 130 in favor. By saying enough uncommitted switched so that's equal, we're eventually going to end up with opposed 130, and we've already got 100. Which means we need another 30 somehow. And the final question asks, "If there are still 120 uncommitted . . . .(reflecting) if there are still 120 uncommitted representatives on the bill, how many . . . ? OK! (insight). Our eventual answer should be 150.
7	M:	(Stares at Bob). OK, one thing, maybe we're missing something here. It talks about in favor.
8	B:	All right.
9	M:	And 100 opposed.
10	B:	Yeah?
11	M:	And down here it talks about 120 uncommitted. So maybe what we have here is a number like 230 plus 120, 350 legislators instead of 230.
12	B:	Oh no, I don't think the total number of legislators comes into play, it's not part of the question. There could be 1,000 legislators. . . It's not part of the problem. So go ahead lets (points to screen) and label this guy opposed.

Although Mel has suggested an incorrect total, the problem can in fact be solved successfully starting with Mel's idea of first computing the total number of legislators. The answer can be computed by subtracting from this total the number who voted before

the speech to obtain number originally uncommitted. As the session proceeds, Bob continues to search for a way to display *his* solution while Mel wants to use the system to work out his approach. Ultimately, Bob's solution approach wins out, although Mel's insistence on adding legislators together influences Bob's problem solving, helping him see a way to display the problem tree:

13	B:	The answer is 150. We need to figure out how to graphically display that. There could be a million ways.
//		
14	M:	OK, why don't we start out with how may total representatives there are.
15	B:	I don't think that's defined.
16	M:	OK
17	B:	(Chuckles)
18	M:	Should we do this? (starts to create schema for adding two sets)
19	B:	Well if you wanna draw together exactly to show, I guess you could draw a schema showing the 50 and 80 adding to 130. Then over here tie on a schema, if you want to do the subtraction and actually create the number 30/ (A slash (/) indicates overlapping conversation).
	M:	/OK
20	B:	/to show how many switched. Then tag something onto that to show the effect that if there are still 120/
21	M:	/OK
22	B:	/add those two together and come up with our total of 150.
23	M:	Let's try that.

In the above Bob is building on Mel's idea and enmeshing it with his own. This is the point where mutual understanding begins.

III. Protocol Description: Politics Problem on TAPS Pair 2 (POLT3)

There were numerous and striking parallels between POLT2 and POLT3, a male ("Joe")/female ("Ann") pair that also reached a correct solution but required 24 minutes to do so. Like Bob in POLT2, Joe, as the leader of POLT3, is directive, does most of the reasoning aloud, and tends to ignore or devalue input from his partner. Consequently, the final solution strategy is much more a product of his thinking than hers. Ann, like Mel, tends to demure to Joe's lead.

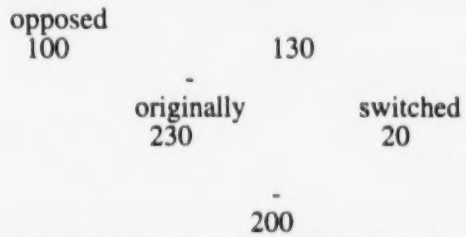
Another parallel is that like Bob, Joe intuits an answer early in the problem-solving session through a process of reflection followed by insight. In neither case did the current screen display seem to be especially helpful in leading to the insight. In both protocols, the problem is recast at the point of insight as one of trying to determine how to use the system tools to explicitly represent the solution that has been found.

Still another parallel is that much of the problem-solving session represents a tension between the same two possible solution approaches. Joe, like Mel in POLT2, favors a part-whole strategy: He first computes the total number of legislators; he is then able to determine how many were originally uncommitted by subtracting those who voted originally. However, Ann initially suggests subtracting the 100 opposed from 130 committed, and then adding this difference to 120. She initiates the computer session by working forward intuitively without a long-term goal or deep understanding, and nearly achieves a correct solution tree. This evolving solution tree is then viewed and studied by the pair, but (interestingly) fails to cue their understanding and is ultimately rejected by Joe. Understanding does not occur because the pair fail to see that the 30 computed by subtracting 100 opposed from 130 committed is also the number of switched votes that can be added to the 120 now uncommitted to obtain the answer. A similar error occurs in PTP11, suggesting the hypothesis that a recurring error situation in problem solving is

when a subgoal set computed in one schema needs to be renamed before is input to a different schema.

Another parallel is the usefulness of the weaker partner's contribution. Just as attending to one of Mel's thoughts cues Bob to the complete solution tree, some assists from Ann are probably helpful, as shown below:

The following representation on the screen is being discussed:



1. J: I don't know what that number can be represented by (rereads part of problem) . . . voted . ./
2. A: (points) /This should be an addition.
3. J: Yeah, I know (minus sign changed to addition; 200 changed to 260). That's 260 have voted so far.
4. A: Yes . . // . . . We're up to no other vote switches took place

A significant added difficulty for the POLT3 pair was that Ann, who initially controlled the mouse, was very unskilled with the computer. Eventually Joe took control of the mouse, but much time was wasted by Ann's ineptness.

Protocol Description: Politics on TAPS, Pair 4 (POLT4)

PTP6 consisted of two females ("Lynn" and "Ruth") who worked the problem incorrectly in 14 minutes. The protocol represents the least effective pair processing of the politics problem on TAPS, yet was literally filled with classic behaviors associated with good problem solving in the cognitive literature. These included "cognitive negotiation," which occurred throughout, and very frequent instances of insight, monitoring, effort to plan, and flexible strategy use. Our descriptive analysis attempts to shed light on how and why these behaviors failed.

The protocol begins with Lynn reading the entire question followed by a mutual conclusion that their first move on the computer will be to compute that 130 are in favor of the bill. Before proceeding, however, they decide to examine the goal question in detail:

1. L: Should we get a schema for that?
2. R: Yeah. Wait, let's look at the bottom question again. What's the question?
3. L: What we're trying to get to? OK, what we're trying to answer is, "if there are still 120 uncommitted, how many were uncommitted before Gov. White's speech? OK.
4. R: Cause there are still 120 uncommitted representatives.
5. L: That means that are against the bill
6. R: Mm-hum
7. L: I guess. (reading) "How many were uncommitted before his speech?"
8. L: //Uncommitted just means they didn't decide? There are still 120 who haven't decided . . .

9. R: Mmm, OK
10. L: Let's see, (reading) "Following his impassioned attack, enough uncommitted voters switched to opposed/
11. L&R: To opposed!
12. L: /so that's the same number . . . (continues reading) . . . in favor of the bill." Ok, so our original number/
13. R: The same number are pledged against as in favor. So after, there was 120 voted for and 120 . . . . no that's not
14. L: No, these are people who haven't decided, right?
15. R: OK
16. L: There are still 120 . . .
17. R: All right, you're right.
18. L: OK, let's go to the beginning
19. D: Let's get how many for and how many against.

The segment above, which illustrates the intensive cognitive negotiation that characterizes the entire protocol, centers around a monitoring sequence whereby Lynn heads off a serious misunderstanding by Ruth of the term "uncommitted." It also illustrates strategy flexibility in that they switch back and forth between a data-driven first step and a heuristically guided examination of the question. There is also a moment of mutual insight regarding the nature of the question.

The pair then sets up their first screen triad connecting two sets: "100-opposed" and "130-in favor," although no arithmetic operator is put in. Strongly miscued by the word "switched," they mutually conclude (incorrectly) that these two sets must be equalized, so 15 voters must be moved from the in-favor set to the opposed set:

20. R: So that means that 15 people had to switch from these people to these people (points to screen) to make it even, right?
21. L: I don't know. (Reads) "If there are still a 120 uncommitted . . ." I don't get it. "Following Gov. White's impassioned attack on the bill, enough uncommitted votes *switched* to opposed . . . " Oh! So some of these (points to "in favor" box on screen) switched to here.
22. R: Right . . . So it means 15 switched over.

However, this conclusion does not lead them closer to a feeling of solution and they become confused. So, they decide to redirect their efforts toward a heuristic strategy based on pulling out numbers from the problem. The reading process activated by this strategy does lead Ruth to a significant insight that none who have voted change, so other votes must be coming in. However, they then decide that the word "switched" indicates otherwise, and Ruth's insight is seemingly abandoned:

23. R: Let's leave that. We can ignore all this. Let's just get the numbers.
24. L: The numbers.
25. R: OK
26. L: 50 and 80 is 130 that are for it.
27. R: OK we got that.
28. L: It says 100 are unalterably opposed
29. R: Right
30. L: "Following his impassioned attack on the bill" . . . . Does that mean his speech?
31. R: OK, yeah. Oh, wait, wait, wait! Enough! We don't switch -- none of these people switch.
32. L: OK.
33. R: I think that's what it's saying/
34. L: /So are people just added to it? "Enough uncommitted votes/

35. R: /Right
36. L: /switched?"
37. R: No, no, it does say *switched.*
38. L: Yeah

This segment is followed by another short period of confusion, followed by further speculation on the meaning of the word "uncommitted." Then there is a sudden, largely correct, insight by Lynn that the answer (originally uncommitted) is obtained by adding the number of switched votes to the 120 still uncommitted votes. However, they are erroneously assuming (functional fixedness) that the number switched is 15, and can't see how the system can be used to compute the 15:

39. L: But wait. (reading excitedly) "If there are still 120 uncommitted representatives on the bill, how many were uncommitted before!" A hundred-twenty plus fifteen!
40. R: How do you get that?
41. L: OK. Cause 15 switched over/
42. R: OK, let's put that/
43. L: Oh, wait. I don't know . . . /
44. R: /It says, ". . . 100 opposed, 130 in favor." So we need to do another schema to figure out . . . fifteen have to switch, but how do we do that on this . . ./
45. L: /So it would be a 120 plus 15?
46. R: I don't know. Yeah.
47. L: Do ya think? I don't know what we do with that, though (pointing to screen).
48. R: No, we can't subtract it. // You start with a hundred each, and then there's thirty extra on one side, so you take fifteen, put them on the other side, then they're equal?
49. L: Yeah, yeah./
50. R: /I don't know how to set it up, though./
51. L: /Why don't we put 130 minus 15/
(they create schema to compute 130 - 15 = 115 and discuss whether to call the sets of 15 "uncommitted" or "switched."

In failing in their attempt to create a schema that will compute the required number (15), they realize that their conceptualization is flawed. This leads Ruth to an important, correct insight: That the number switched is 30. However, Lynn argues (incorrectly) that there is no meaningful semantic term for the 30:

52. R: //A hundred and fifteen. That's not what we want (laughs).
53. L: (Laughs) No, it's not!
54. R: We want a thirty -- we want a thirty here!
55. L: What are you gonna say the thirty is, though? What is it? Thirty is nothing.
56. R: Thirty is the in fav . . . all right . . . do you see what I'm saying, though. I don't know how to put in the schema box.

Lynn influences them to abandon Ruth's potentially productive thinking. They erase a begin anew with a new strategy of simply creating the goal schema:

57. L: You know what? Why don't we just erase this and work backwards, and take "If there are 120 uncommitted," and then take 120 + 15 and we'll get our answer.

Lynn guides creation of the following schema: 120-uncommitted originally + 15-switched = 135-uncommitted in beginning. They conduct a negotiated self-checking session to confirm their understanding and conclude that although they "kind of set it up backwards," that the problem was at fault for the difficulties because it was ambiguous.

Protocol Description: Politics Problem on Paper, Pair 1 (POLP1)

Two females, "Alice" and "Jan" solve the problem correctly in three minutes. In the first 30 seconds, Alice reads the problem. They express lack of understanding and collaborate in writing down the following:

Opposed	In favor
100	130

They reflect on this (talking and mumbling to themselves) for about 30 seconds, then Alice decides they must remove 15 from "in favor" and put it in "opposed," and Jan agrees. At this point they read and reread second half of the problem until Jan experiences sudden insight:

3.	J	Oh, no, no, this is wrong (erases the number 15 from paper)! It didn't take away from the in favor, it took away from the uncommitted. So 30, if 30 came away from the uncommitted after the speech, then there was 150 before. (Writing on paper) So 150 committed . . ./
4.	A	No . . ./
	J	Uncommitted before the speech.
5.	A	Where does it say that? I was . . ./
6.	J	/Because you have to . . . We had 130 in favor and 100 opposed . . . and when he uh, after the speech there were 120 uncommitted. So we add the uncommitted over here (points)
7.	A	OK
8.	J	So this is after the speech we have 120. Thirty of these/
9.	A	/Uh hum . .
	J	/people left to go to the opposed.

II. Protocol Description: Politics Problem on Paper, Pair 2 (POLP2)

Two females, "Clara" and "Dawn," solve the problem in approximately 8 minutes. In this protocol, major problems occur due to poor reading comprehension. Poor comprehension occurs even though much of the problem solving time (68%) is spent in reading and rereading activity, which seems to be indicative of a struggle to understand. Difficulties may occur due to the conversational "style" of the pair. The dialogue is broken, almost non-sensical, and filled with interruptions. The logical thread in this "discussion" is often difficult to find.

The first minute is spent reading: Clara begins and then asks Dawn to take over reading in middle of problem. The word "unalterably" is changed to "alternatively" by Dawn. When Dawn completes reading, she makes following notes on the paper:

"50 min" "80 min" "100 opp"

They both reread the problem, express confusion, followed by Dawn's mentally adding 50 plus 80, although she does not clearly identify what objects are being added. The dialogue that follows is broken, almost non-sensical, and filled with interruptions. The logical thread in the following "discussion" is difficult to find:

1. C I'm confused
2. D So am I
3. C It's right here (points to paper)
4. D 50 + 80 is 130, right?
5. C Uh hum
6. D So there are 130 people that . . .
7. C So . .
8. D 100 (pause) are opposed to that . . .

//

(reading and mumbling)

//

9. C Where's White? We got Black (points to problem)
10. D No

//

11. D Oh wait, here, Gov White's impassioned attack on bill.
12. C OK, so I got a different one (both giggle)
13. C Gov Black pushing new college loan. Gov White attacks it.
(Writes on paper:)

Black New college loan White attacks

14. C So we got 50 minority and 80 majority representatives, which doesn't mean a whole lot, does it? OK and so . . . 100 representatives today are opposed to the bill . . . so 100 are with White.
15. D Right
16. C OK (then reads): "The same number are pledged against."
So it's 100 and 100 (writes 100 next to both Black's and White's names)
17. D There are only 130 people there.
18. C Is this a percentage? (laughs)
19. D There are still 120 uncommitted representatives on this bill, how many are . . ./
20. C /Well if it's the same, then . . . Can't you kind of . . ./
21. D Well, there are only 100 . . ./
22. C /5 and 5? 100% of 5 and 5
23. D That doesn't make sense.
24. C No, that can't be.
25. D This shouldn't be this difficult.

In sum, the partners seem to be attempting to determine how many representatives are with White, and how many are with Black, although Clara's focusing on the sentence "the same number are pledged against" causes her to incorrectly believe that 100 representatives (instead of 130) are with Black. Then, Dawn states her (incorrect) belief that there are only a total of 130 representatives altogether, leading Clara to wonder whether the numbers in the problem might refer to percentages, although this idea doesn't make sense and they abandoned this direction.

At the four minute mark, both girls are re-reading the problem to themselves, when Clara points to the key word "unalterable" and asks:

26 C: Is this word (points) something that we . . . gonna throw it off?
27 D: I don't know. Well, they're not going to change. Alter.

This is followed by more rereading followed by an exchange that focuses on the word "uncommitted," and an incorrect inference by Clara that 100 uncommitted votes switched to opposed. But this idea leads to nowhere:

28	C:	Uncommitted votes. Where is the uncommitted? Which is 120 (writes this down). 100 uncommitted votes switched to opposed so that the same number of representatives . . ./
29	D	/So there has to be . . /
30	C	/So then like there's a hundred; So there's like 20 left over of the uncommitted, right?
31	D	What do you mean?
	C	Well enough, well, we got the uncommitted here.
32	D	Right
33	C	So, enough of them switched over. At least 100 of these switched . . . ///
34	D	/There's 120 left over
35	C	That has nothing to do with that.

A critical insight occurs that they are supposed to be determining how many were uncommitted before the speech. They almost settle on the number 100, which appears to be a guess rather than a conclusion based on understanding. But the sense that they are missing something encourages them to continue

36	C	Before!! How many were before Gov White's speech?
37	D	Well, if 100,. we don't know how many are committed before that
38	C	Do we get a time limit? (interviewer responds no)
39	D/C	(Laughter) Oh, darn!
40	C	We feel comfortable with this answer: 100 representatives are opposed to the bill (writes this down)
41	D	Right!
42	C	We're missing something here I think (circles top half of problem, and both begin to reread)

At the 6.35 minute mark, while rereading the problem, both realize that they have not considered an important fact in the problem statement.

43	D	130 are in favor. Duh. In favor
44	C	We totally missed that sentence!
45	C/D	OK, 130 . . .

This insight leads Dawn to incorrectly infer that 15 have to switch (from in favor to against) in order to balance the two sides. However both feel uncertain, which leads them to reconsider this conclusion:

46	D	They're not all switching over so there's even numbers here.
47	C	So we have 130 in favor and 100 against, right?
48	D	Yes, so 15 have to switch over.
49	C	Oh that's what they're saying?
50	D	I don't know, is it?

In the following segment, understanding of the key insight gradually builds, beginning with a key idea by Claire that thirty new votes are needed to make the two sides even. To this Dawn adds the idea that these 30 were uncommitted before they

voted. Claire does not follow Dawn's reasoning at first as she is fixated on the idea that votes switched from pro to con, but the exchange continues as Dawn scaffolds Claire toward understanding. To aid their discussion, they draw circles and numbers, representing sets and set values, on the page and point to them:

51	C	How many were uncommitted before . . .impassioned . . . . Well, 30. Thirty to make them even.
52	D	Thirty were uncommitted before they switched over to there.
53	C	I don't follow . . . So we have 130.
54	D	Following Gov White's impassioned attack on the bill, enough uncommitted votes switched to opposed so that the same number of representatives pledged against the bill.
55	C	So they came over
56	D	No, nobody came over. This is the uncommitted pile.
57	C	This is still, this is still . . ./
58	D	/Plus "X"
59	C	Plus "X"
60	D	OK, so 30 more have to go there.
61	C	Yes, from here (pointing to circle on paper)
62	D	So the "X" would be thirty
64	C	Right
65	C/D	That'd be a total of 150 uncommitted.

III. Protocol Description: Politics Problem on Paper, Pair 3 (POLP3)

In this protocol a male (Mac) and female (Francis) solve the problem correctly in 3.5 minutes. Francis is the leader throughout, thinking aloud and explaining her thinking, although Mac makes valuable corrections and contributions. Although he is more passive partner, he is actively understanding. There are no errors in protocol. This is a good example of a protocol where one person is in the lead, but more passive partner is helpful and "withit." There is mutual support: He points out something she overlooks, she explains her insights to him and corrects him when he is thinking incorrectly. The problem is fairly easy for them.

Francis begins, reading the entire problem in 1 minute. She writes some notes (50 minority, 80 majority, Gov. White against) as she reads. When done, she chuckles, exclaims, indicating incomplete understanding. She concludes 80 plus 50 are in favor and it doesn't matter whether they are minority or majority, so adds them to get 130.

Mac then speaks (after 1.5 minutes) and summarizes: 130 for and 100 against. Francis didn't notice the 100 against, but Mac points this out and Francis agrees that 100 are against, emphasizing <u>today.</u>

Francis continues: Reads: following speech enough uncommitted switch so that same number are against as in favor (Mac echoes). If there are still 120 uncommitted . . .

At this point Francis has insight that 30 switched, and at first Mac doesn't agree, but quickly begins to experience the insight too:

1.	F	If there are still 120 uncommitted voters, how many were uncommitted . . . Oh, 20, 30. If there were . . ./
2.	M	/Well, fifteen had to . . ./

3.	F	/Fifteen?
4.	M	Had to switch I mean.
5.	F	But if there was 130 . . I/
6.	M	Aha!
7.	F	130 were in favor, 100 weren't, so now there's the same number for and against?
8.	M	Right, so now/
9.	F	/Thirty people, 30 uncommitted have to switch?
10.	M	They didn't switch though, they just voted.
11.	F	I mean voted
12.	M	Yeah

Francis then questions why they are told that 120 are uncommitted, and then realizes what the goal of problem is. She explains her thinking:

13.	F	So it doesn't really matter that there's 120 uncommitted? . . . Oh, maybe it does. Oh but wait, no, it does because that means there were 150 people. Cause if they want to know, there's still 120 uncommitted after 30 of them went against, so before there were 150?
14.	M	(Reflecting, observing)

Francis continues to repeat her explanation and understanding, and Mac eventually confirms his understanding by completing thoughts:

15.	F	Or, if 30 people went against/
16.	M	/Then that leaves 120.
17.	F	Yeah.
18.	M	150.
19.	F	So that means 150, uncommitted before speech.